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HERMES : A PERSONAL-COMPUTER PROGRAM FOR CALCULATION OF THE FERMI-GAS MODEL PARAMETERS OF NUCLEAR LEVEL DENSITY

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HERMES: A Personal-computer Program for Calculation of the Fermi-gas Model Parameters of Nuclear Level Density

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A computer program, HERMES, that provides the quantities usually needed in nuclear level density calculations, has been developed. The applied model is the standard Fermi Gas Model (FGM) in which pairing correlations and shell effects are opportunely taken into account. The effects of additional nuclear structure properties together with their inclusion into the computer program are also considered. Using HERMES, a level density parameter systematics has been constructed for mass range $41 \leq A \leq 253$.

Keywords: Fermi-gas Model, Nuclear Level Density, Level Density Parameters, Level Density Parameter Systematics, Pairing Correlations, Shell-effects

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ＨＥＲＭＥＳ：原子核準位密度のフェルミガス模型パラメータ計算のための パーソナルコンピューター用プログラム

日本原子力研究所東海研究所原子炉工学部
Ａｌｂｅｒｔｏ　ＭＥＮＧＯＮＩ*・中島　豊

（1993年８月24日受理）

原子核の準位密度計算に通常必要とされる物理量を計算するプログラムＨＥＲＭＥＳを開発した。核内核子の対相関と殻効果を取り入れた標準のフェルミガス模型をモデルとして用いた。その他の原子核構造の性質の効果のプログラムへの組み込みについても議論した。ＨＥＲＭＥＳを用いて質量が41から253までの質量領域において準位密度パラメータの系統式を作成した。

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1. INTRODUCTION

The calculation of nuclear level densities at excitation energies of a few MeV can be performed using the Fermi-Gas model (FGM). A certain number of modifications of the basic FGM are necessary in order to take into account nuclear properties of various nature. For example, corrections due to pairing correlations and shell inhomogeneities have to be incorporated to provide a realistic description of nuclear excitations.

On the other hand, an important, experimentally reachable quantity which allows for testing nuclear models employed in level density calculation is the average spacings of s-wave neutron resonances, $<D>_{l=0}$. A large set of information on this quantity has been collected and compiled several times in the past. A relatively recent compilation[1)] has been made available which provides a large data-base on which the traditional level density models can be tested.

We have coded the FGM prescriptions into a computer program, HERMES, which provides the nuclear level density parameters based on fundamental nuclear structure information and on the experimental average spacings of s-wave neutron resonances. The program has been written in order to provide the user with the basic parameters usually employed in level density calculations. The parameters supplied by HERMES should be largely compatible with the parametrization adopted, for example, in codes using the Hauser-Feshbach statistical theory for the calculation of nuclear cross sections. HERMES has been made to be run on personal computers. It would be, however, trivial to separate and include its basic components into any larger code for nuclear reaction calculations.

The details of our model description with some discussions on the various nuclear structure effects included into the FGM are given in our previous paper[2)]. Here we will limit ourselves to give the definition of the basic quantities for nuclear level density calculation and we will then describe the computer program. Finally, examples will be presented to show the capabilities of the use of HERMES.

The program, together with the data-base files are available upon request to the authors (see the request-form in the Appendix).

2. BASIC RELATIONS FOR THE NUCLEAR LEVEL DENSITY DESCRIPTION

2.1 The Fermi-Gas model

The state-density for a set of A non-interacting nucleons (Z protons and N neutrons) arranged on a single-particle spectrum with spacing g_f at the fermi energy can be easily derived to give[3)]

$$\rho_{Z,N}(U) = \frac{\sqrt{\pi}}{12\, a^{1/4} U^{5/4}}\, e^{2\sqrt{aU}} \tag{1}$$

where U is the available excitation energy and $a \equiv (\pi^2/6) g_f$ is a level density parameter.

The density of nuclear *levels*, i.e. states of given total angular momentum J and fixed parity Π
is given by

$$\rho_{Z,N}(U,J,\Pi) = \rho_{Z,N}(U)\, f_\sigma(J)\, g_{par}(\Pi) \tag{2}$$

where $f_\sigma(J)$ can be derived by differentiating respect to state with $M = J$ and $M = J + 1$ a gaussian distribution for the projection of the total angular momentum, M, with dispersion σ :

$$f_\sigma(J) = \frac{2J + 1}{2\sigma^2 \sqrt{2\pi\sigma^2}}\, e^{-\frac{J(J+1)}{2\sigma^2}} \tag{3}$$

and $g_{par}(\Pi)$ is a function describing the parity distribution.

Nuclear energy levels have a clearly unsymmetrical parity distribution in the lower part of the spectrum. As the excitation energy increases, however, the number (or density) of levels with opposite parity tends to be the same. Except for some light nuclei, the parity distribution at excitation energies corresponding to the neutron separation energy can be assumed to be symmetrical. To treat the cases in which the parity distribution is asymmetrical some technique has been proposed[4)]. The possibility of including this effect has been analyzed in several practical applications but a systematic analysis on a large mass range has not yet been done. For this reason the commonly adopted assumption of equal probability for different parity states has been adopted in the present analysis:

$$g_{par}(\Pi) = \frac{1}{2}\,. \tag{4}$$

In addition to the parameter a, the only other quantity to be determined in Eq. (2) is the spin dispersion factor σ. For a gas of fermions constrained into a spherical box of radius R, the dispersion factor σ can be evaluated to give

$$\sigma^2 = \frac{2}{5} (M_n R^2/\hbar^2) A T \tag{5}$$

where M_n is the nucleon mass and T the nuclear temperature in MeV units. This is equivalent to consider the rotation of a rigid body with moment of inertia

$$I_r = \frac{2}{5} A M_n R^2 \tag{6}$$

which furnishes

$$\sigma^2 = \frac{I_r}{\hbar^2} T = 0.01389 A^{5/3} T \tag{7}$$

when using $R = 1.2 A^{1/3}$ fm and $M_n = 938.926$ MeV.

If the condition of spherical symmetry is released, the moments of inertia for an axially symmetric deformed rigid body with deformation ε become

$$I_\perp = I_r (1 + \frac{1}{3} \varepsilon) \tag{8}$$

and

$$I_\parallel = I_r (1 - \frac{2}{3} \varepsilon) \tag{9}$$

for rotations perpendicular and parallel to the symmetry axis (Eq. (8) and Eq. (9) respectively). In this case the spin dispersion factor becomes

$$\sigma^2 = \frac{I_\perp^{2/3} I_\parallel^{1/3}}{\hbar^2} T \tag{10}$$

In the equations above, the nuclear deformation ε is a parameter related to the nuclear quadrupole deformation by $\varepsilon = 0.945 \beta_2$.

In the thermodynamical approach, the nuclear temperature is defined by the relation

$$\frac{1}{T} \equiv \frac{1}{\rho} \frac{d\rho}{dU} . \tag{11}$$

For the Fermi-Gas, the relation

$$U = a T^2 \tag{12}$$

is usually adopted for defining the nuclear temperature. It is however straightforward to derive the value of the temperature from the state-density of Eq. (1):

$$\frac{1}{T} = \frac{1}{\sqrt{U/a}} - \frac{5}{4U} . \tag{13}$$

2.2 Pairing and shell-effects

The calculation of the level density using Eq. (2) is affected by the assumptions made when deriving the state-density from the thermodynamical equilibrium conditions (saddle-point inversion method, continuous approximation) as well as from the assumptions underlying the FGM itself. Quite generally the assumptions made in deriving Eq. (2) are well justified for excitation energies of a few MeV. In particular those approximations are generally valid for excitation energies corresponding to the neutron binding energy. This is an important point because at that energy the density of nuclear states of given J and Π is known from the spacing of neutron resonances (usually s-wave neutron resonances). In these cases it is possible to evaluate the only parameter of Eq. (2), a, from

$$<D>_{l=0} = \frac{1}{\rho_{Z,N}(U,J=1/2,\Pi)} \tag{14}$$

for nuclei with $I_\alpha = 0$, or

$$<D>_{l=0} = \frac{1}{\rho_{Z,N}(U,J=I_\alpha + 1/2,\Pi) + \rho_{Z,N}(U,J = I_\alpha - 1/2,\Pi)} \tag{15}$$

for nuclei with $I_\alpha \neq 0$, where I_α is the spin of the nucleus with Z protons and N - 1 neutrons (target nucleus in the neutron + (Z , N-1) process). From the experimental $<D>^{exp}_{l=0}$ it is possible to derive the systematics of the level density parameter a.

The level density parameter a thus determined shows strong fluctuations over the entire mass range, essentially due to paring correlations and shell inhomogeneities (see Fig. 2 below).

A full treatment of the pairing correlation in nuclear motion may be based on statistical as well as on BCS theories[5]. However, a much simpler but effective treatment of this effect can be incorporated into the model description simply redefining the excitation energy of the Fermi-Gas according to

$$\begin{aligned} U \rightarrow U - \delta \quad \text{where} \quad \delta &= 2\Delta \quad \text{for even-even nuclei} \\ &= \Delta \quad \text{for odd nuclei} \\ &= 0 \quad \text{for odd-odd nuclei.} \end{aligned} \tag{16}$$

The pairing correlation parameter, Δ, may be derived from mass-differences of neighboring nuclei for the entire mass region. However, the values derived from the experimental nuclear masses may be well represented by a simple, smooth function of the mass number. For example the value[6]

$$\Delta = \frac{12}{\sqrt{A}} \tag{17}$$

has shown to be suitable for representing the experimental situation.

The use of this simple prescription may well be questioned from theoretical point of view since the relation (17) has been derived from even-odd difference in nuclear masses, i.e. at zero temperature. The situation may be different at finite temperature. However, using this simple procedure we have obtained good results as far as the level density parameter systematics is concerned (see below).

The inclusion of shell effects into the FGM description has been carried out using different approaches in the past. In our analysis we have adopted a technique due to Ignatyuk and coworkers[7]. In this approach the level density parameter a depends on the excitation energy as well as on the shell correction energy E_{sh}:

$$a(U) = a(*) \left[1 + \frac{E_{sh}}{U} (1 - e^{-\gamma U}) \right] \tag{18}$$

where $a(*)$ is the asymptotic level density parameter to which $a(U)$ tends for high excitation energies and γ a damping parameter.

The shell correction energy E_{sh} is defined as the difference between the experimental nuclear mass and a smooth theoretical mass value, M_w, derivable, for example, from a liquid-drop model:

$$E_{sh} \equiv M_{\exp} - M_w \ . \tag{19}$$

The evaluation of this quantity requires some care because different liquid-drop model parametrizations are available from literature and they produce quite different values for E_{sh}.

Following this approach, for each isotope, the level density parameter $a(*)$ is to be determined from the average neutron resonance spacing. In fact, the shell correction energy can be evaluated using Eq. (19) and the corresponding level density parameter a can be adjusted to fit the experimental $<D>^{\exp}_{l=0}$ by varying $a(*)$.

2.3 Inclusion of other nuclear structure effects

The contribution of collective degrees of freedom in nuclear excitations is very important and different techniques have been proposed for its inclusion into the Fermi-Gas description. It is possible to show[8] that the contribution of collective excitations to the state-density can be factorized into the form

$$\rho_{Z,N}(U) = \rho^{i}_{Z,N}(U) \ Z_{coll} \tag{20}$$

where Z_{coll} is the partition function for the collective degrees of freedom of the system with excitation energies E_c

$$Z_{coll} = \sum_{c} e^{-\frac{E_c}{T}} \tag{21}$$

and $\rho^{i}_{N,Z}(U)$ is the state density for the intrinsic (non-collective) excitations.

Various models have been employed in the past to evaluate the contribution of collective degrees of freedom to nuclear excitations[6,7]. In the case in which the nucleus has an axi-symmetric deformation, the rotational degrees of freedom are expected to play an important role at excitation energies around the neutron binding. In this case the collective enhancement factor can be promptly evaluated as

$$Z_{coll} = \sigma_{\perp}^{2} = \frac{I_{\perp}}{\hbar^{2}} T \ . \tag{22}$$

A similar, simple, analytical expression can be derived also for nuclear excitations due to surface vibrations.

These prescriptions cannot be applied to the complete mass range. In fact, they assume the nucleus to have either rotational or vibrational degrees of freedom to be added to the intrinsic excitations. This classification is in many cases not possible.

A model which provides a unified description of collective properties of nuclear spectra is the Interacting Boson Model[9]. Recently[8], this model has been applied for the evaluation of the collective enhancement factor Z_{coll}. However, the calculations made using this technique are still too involved to be enclosed into a simple recipe and in HERMES only the simple expression of Eq. (22) has been considered.

The relations given above have been coded into a computer program, HERMES, whose description and use will be given in the next chapter.

3. HERMES

3.1 Introduction to HERMES

We will describe here the computer program HERMES. The program has been written in Fortran 77 and the source contains about 2000 records, excluding the *block-data* containing the experimental nuclear mass differences.

The program has been written in such a way that it runs interactively with the user. We will first describe its structure (section 3.2) and the various *menus* which are presented to the user while running it. At the mean time we will provide a brief description of the various physical assumptions made. The explanations on how to install the program, the description of the various files that the program uses and other technical details will be given in the sections 3.3 and 3.4.

The input/output of HERMES should be self-explanatory. We will give here the explanations for only a few examples of the various paths that can be followed when running HERMES. The name of variables or other quantities appearing in the program input/output will be given in a different type-style (like in `type-style`).

3.2 Structure of HERMES

The structure of HERMES is shown in the flow-chart of Fig. 1. We give here a few examples of how the interactive procedure works. The program starts submitting the first menu:

```
M a i n   M e n u
-----------------
 1) Start the calculation for a given isotope
 2) Set/Reset defaults for the calculation
 3) Build the systematics of LDP
99) STOP
```

As it is obvious, three selections can be made, in addition to the `STOP` (to end the execution).

Typing `1` the program will calculate the level density parameters for a single isotope. In this case the next request will be for the `Mass number and Atomic number` of the isotope under study.

To calculate the level density parameters, a certain number of options need to be specified. The program starts with all the possible options set to default values. To change and/or select options different from the defaults, the selection `2` in the main menu above should be made. For example, the calculation of the spin dispersion factor σ can be made assuming the nucleus to be spherical or deformed. Eq. (7) will be used in the former case and Eq. (10) in the

latter. The selection of one those two options can be made following the selction 2 in the main menu.

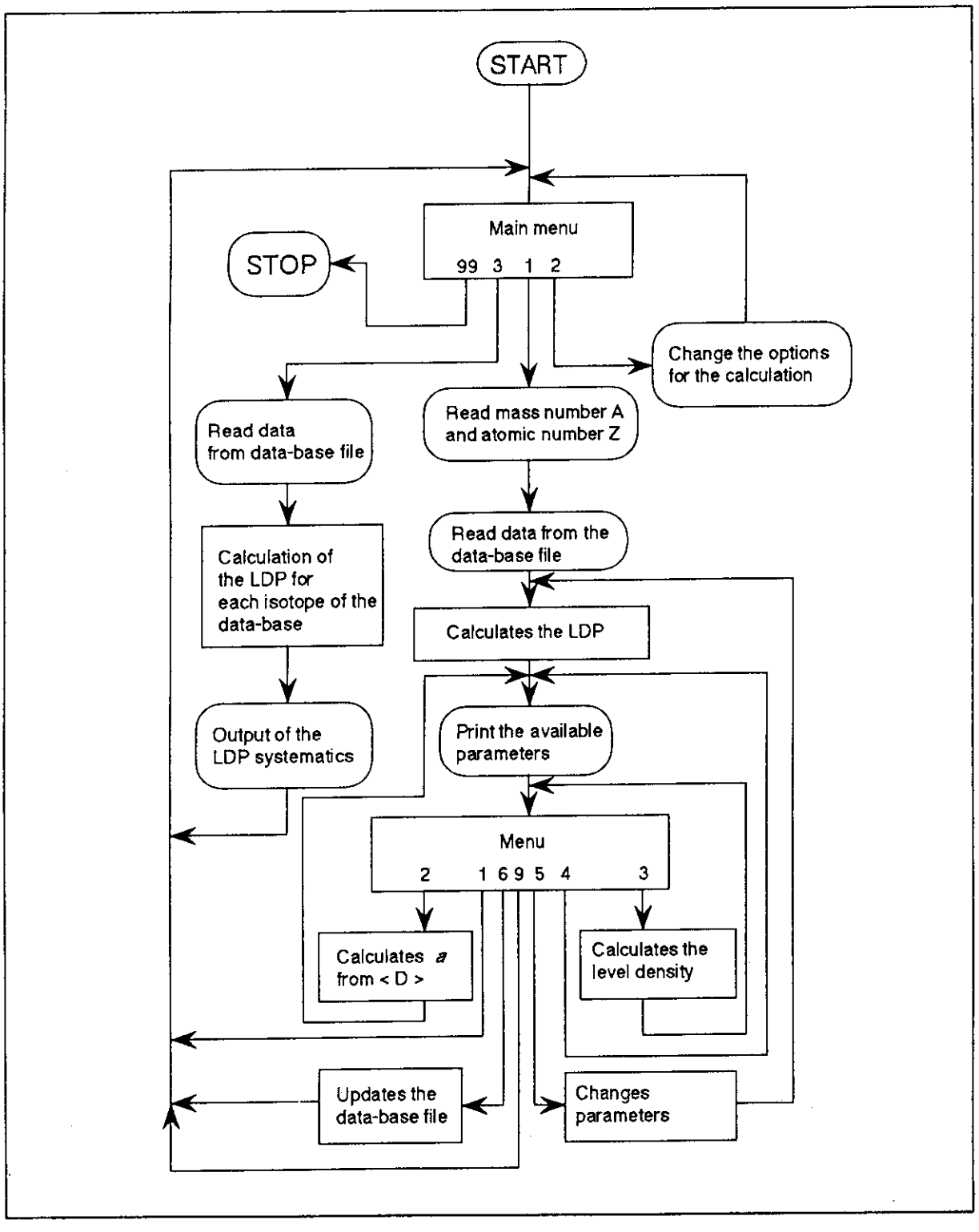

Figure 1. Flow-chart of HERMES.

Finally, typing 3 the program will construct the level density parameter systematics for all the nuclei contained in the data-base, using the options *currently* available.

If the selection 1 was to be made and the nuclear information are contained into the data-base file, the calculation of the level density parameters for the selected nucleus will be promptly performed. These includes the calculation of the spin dispersion factor σ^2 (sigma2), the shell correction energy E_{sh} (Esh) according to a specified liquid-drop mass formula, the level density parameters $a(*)$ and a, the nuclear temperature T and so forth.

The resulting values will appear as

```
Parameters actually available:
****  153Sm  ****
Atomic number Z= 62   Neutron number  N= 91
Target spin-parity      :            .0+
Neutron binding (Sn)    :      5.86737    MeV
En (above Sn)           :       .00000    MeV
delta (back-shift)      :       .97014    MeV
U (Sn+En-delta)         :      4.89722    MeV
Temperature             :       .52312    MeV
Shell correction (Esh)  :      3.67499    MeV
Deformation (Beta2)     :       .00000
Zcoll (J=|It-1/2|)      :      1.00000
Zcoll (J= It+1/2 )      :      1.00000
sigma2                  :     31.80023
gamma                   :       .07479    MeV**-1
a(*)-from systematics   :     18.69185    MeV**-1
a                       :     22.99348    MeV**-1

Experimental <D(l=0)>   :       .05180 +/-       .00330 KeV
Calculated   <D(l=0)>   :       .05961                  KeV
             <D(l=1)>   :       .02050                  KeV
```

Immediately after, the following menu will appear

```
M e n u
1) Change Isotope
2) Calculate  a  and  a(*)  from given <D(l=0)>
3) Calculate the level density
4) Display available parameters
5) Change the parameters
6) Update the data-base file
9) Return
```

Selection 2 is particularly important because it provides the evaluation of the level density parameters that fit the experimental $<D>^{exp}_{l=0}$.

Selection 5 will give the user the opportunity to change individual parameters and repeat the calculations using the updated values. For example, if the user provides the value of the collective enhancement factor Z_{coll} evaluated using an independent technique, the evaluation of the level density parameters may be repeated taking into account of collective enhancement.

Finally, in Table 1 we give a list of the options that can be selected, if requested, selecting 2 in the main menu.

Table 1 List of the options that can be selected in HERMES' main menu.

Heading	Selections	Action
Pairing (back-shift)	1*	pairing correction energy δ calculated according to Eq. (16)
	2	pairing correction energy δ as in selection 1 but with $\delta=0$ for odd-mass nuclei
	3	no pairing correction included
Mass formula	1*	Mass formula from Myers and Swiatecki[10]
	2	Mass formula from Spanier and Johansson[11]
	3	Mass formula from Möller and Nix[12]
Nuclear deformation	1*	Deformation β_2 read on the data-base file
	2	Deformation β_2 calculated as in the reference[11]
	3	Deformation β_2 calculated as in the reference[13]
Damping parameter γ	1	constant
	2*	$\gamma = 0.40 / A^{1/3}$
	3	$\gamma = k / A^{1/3}$, k in input
Collective enhancement	1	Z_{coll} calculated as in Eq. (22)
	else*	$Z_{coll} = 1$
Nuclear temperature	1	$T = (U/a)^{1/2}$
	2*	T as defined in Eq. (13)
	3	T calculated by numerically differentiating the total state density

*default value.

There are two experimental mass-excess tables included in HERMES[14]. In our previous work[2] we have used the mass table from the CERN compilation. Here, we have used the more recent tabulation of Waspra et al.[14]. This alternative choice resulted in a very small difference in the parameter systematics.

The routine that produces the mass difference is kept separated from the main program. In this way, each one of the two compilations, or any other additional mass compilation, can be readily incorporated into the program.

3.3 File allocation

HERMES requires the allocation of a maximum of three files. One contains the data-base of nuclear information required to calculate the level density parameters. This file is provided together with the computer program.

A second file allocation is required if a systematics of parameters is being constructed by the code. A version of this file, obtained using all-defaults for the calculation is given in Appendix A.

Finally, if the information for a given isotope is not contained in the data-base file or if it is contained but needs to be updated, a new version of the data-base file can be created by HERMES. This new version of the data-base file can be subsequently used as *input* data-base for further runs.

3.4 Installation

HERMES can be requested to the authors using the attached form (see Appendix B). The program and its files will be delivered in a diskette or through electronic-mail. In either case, the package will include:

1) the HERMES source program
2) a subroutine containing the experimental mass differences
3) a data-base file containing the nuclear structure information
4) the executable file for running HERMES on a personal computer (only in the diskette)

Independent compilers and linkers can be used to produce the executable file. We can provide the executable files compiled and linked using the Microsoft Fortran (ver 5.1), for either IBM (compatible) or NEC (compatible) personal computers.

The whole program has been divided into

```
-hermes.for
-mass.for
```

files (the source and the mass-excess block-data routine). They can be compiled and liked separately or merged first and then compiled and linked as a unique program.

In summary, the HERMES package contains:

Directory	Files	Contents
source	hermes.for	HERMES fortran source
mass	mass.for, mass.lib	mass-table (Ref.[14a])
	newmass.for,newmass.lib	mass-table (Ref.[14b])
exenec/exeibm	h.exe	HERMES executable file
	h8x87.exe	HERMES executable file (math-coprocessor i8x87 required)
data	datab.dat	data-base file
	syst.dat	file containing the level density parameter-systematics
	updatab.dat	updated version of the datab.dat file
	startup.txt	mask text-file

4. EXAMPLES OF USE OF HERMES

4.1 Construction of the FGM parameter systematics

As an example of the use of HERMES we show here how to construct a level density parameter systematics using various options available in the program.

The construction of the nuclear level density parameter systematics has been performed several times in the past, perhaps the most quoted and recognized being those of Erba et al.[15], Lynn[16] and Dilig et al. We have used the data on experimental nuclear level spacings $<D>^{exp}_{l=0}$ from the reference[1] and then calculated the level density parameter a (selection 3 in the main menu of HERMES).

The results are shown in Figure 2. For clearness, a portion in a restricted region, $100 \leq A \leq 200$, is given separately.

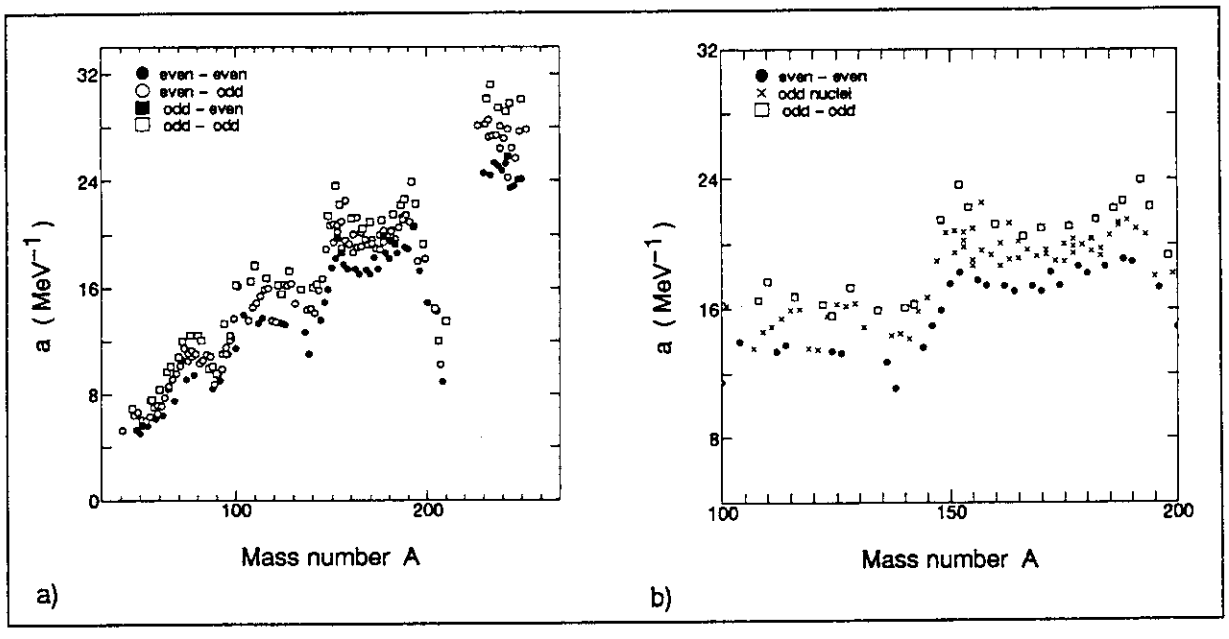

Figure 2. Level density parameter a from Eq. (2) for $41 \leq A \leq 235$ (a) and for $100 \leq A \leq 200$ (b).

In making Figure 2, no corrections to the FGM expressions were applied. However, as described in chapter 2, paring and shell effects can and should be incorporated into the FGM in order to have a more reliable parameter systematics.

In fact, repeating the calculations made for Figure 2 and including the prescription of Eq. (16) to correct the FGM for pairing correlation effects, we have obtained Figure 3. As can be seen, the even-odd dependence of the a-parameter in the systematics is strongly reduced.

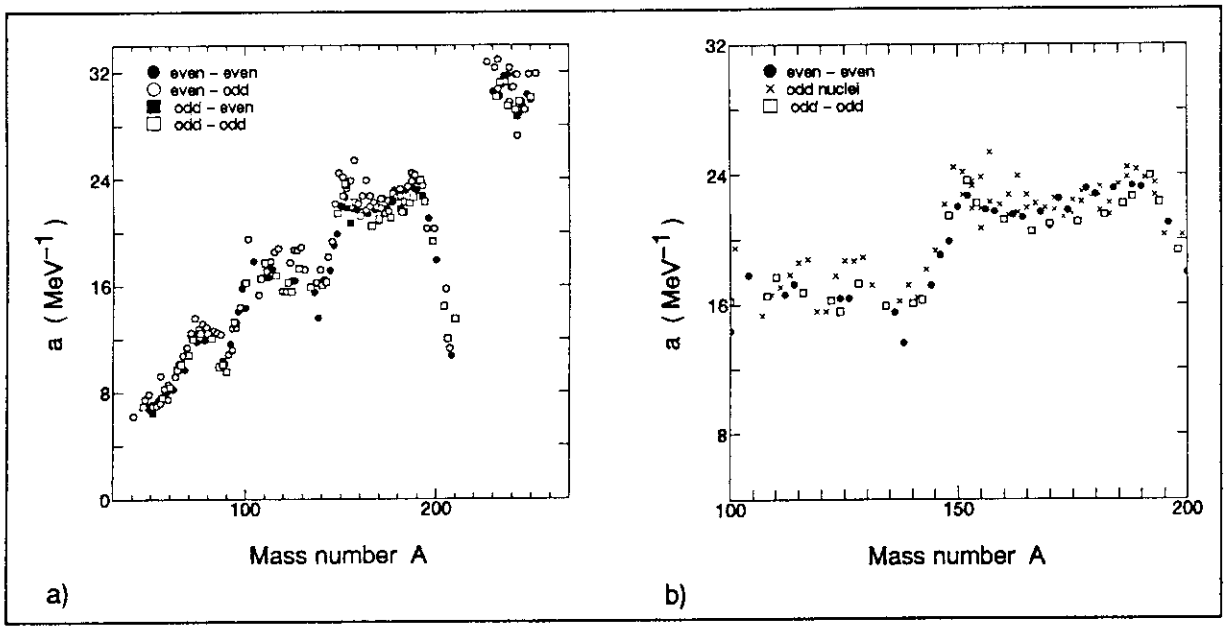

Figure 3. Level density parameter a from Eq. (2), with paring correction included, for $41 \leq A \leq 235$ (a) and for $100 \leq A \leq 200$ (b).

Shell effects are clearly present in the systematics of Figure 3. Using the technique described in 2.2, we have repeated the calculations for the nuclei in our data-base and built the systematics of the $a(*)$ parameter.

The results of the calculations are shown in Figure 4.

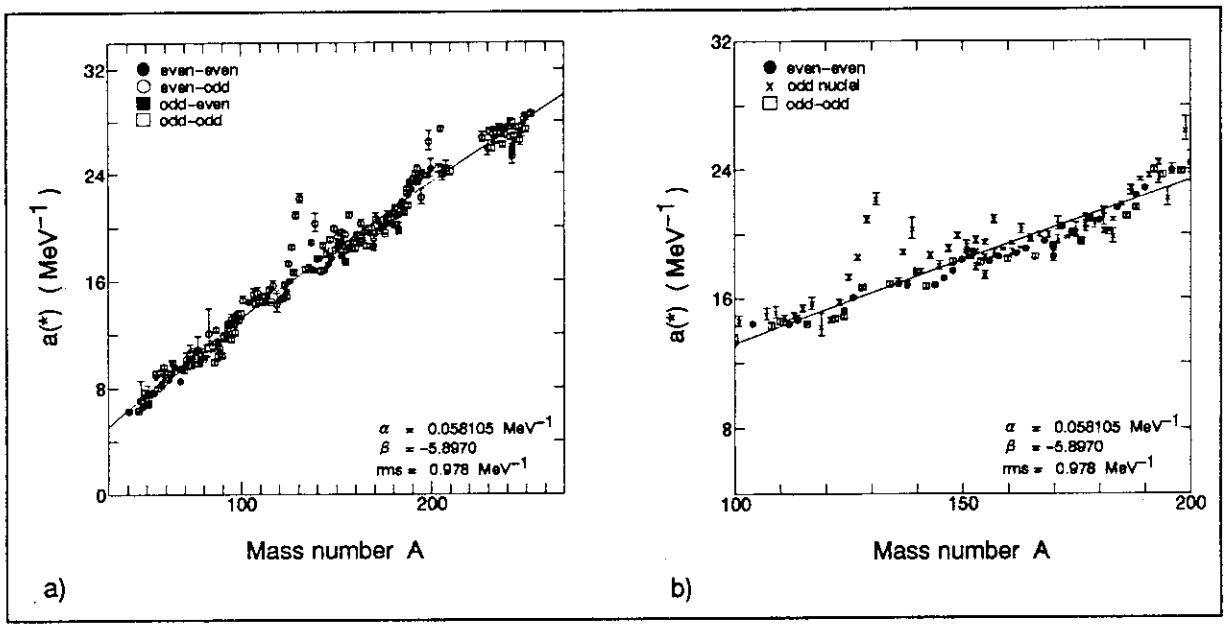

Figure 4. Level density parameter $a(*)$ from Eq.(18) for $41 \leq A \leq 235$ (a) and for $100 \leq A \leq 200$ (b).

It clearly appears that the shell effects have, to a great extent, been appropriately taken into account by the procedure described above.

In Figure 4 we also show an evaluated "experimental" error associated to each $a(*)$. This is just the direct effect of the experimental uncertainties on $<D>^{exp}_{l=0}$. The value of the damping parameter γ adopted in our calculation was[17)]

$$\gamma = \frac{0.40}{A^{1/3}} \qquad \mathrm{MeV}^{-1} . \tag{23}$$

The systematics of the $a(*)$ parameter shown in Figure 4 can be well described by a smooth function of the mass number A

$$a(*) = \alpha A(1 - \beta A^{-1/3}) \tag{24}$$

where the two parameters α and β can be determined from a least-squares fit of the $a(*)$ values. From the values plotted in Figure 4 we have obtained

$$\alpha = 0.058105 \ \mathrm{MeV}^{-1} \qquad \text{and} \qquad \beta = -5.8970 \tag{25}$$

with root mean square deviation, $rms = 0.978\ \mathrm{MeV}^{-1}$.

This parametrization can be used to evaluate the level density parameters in the expression Eq. (2), for nuclei whose experimental information on the average level spacings is not available. In fact, from the value of $a(*)$ obtained in Eq. (24), the level density parameter a can be calculated using Eq. (18) and the spin dispersion factor σ using Eq. (7) or Eq. (10).

For a more accurate analysis of our results, we have performed a least-squares fit to the $a(*)$ calculated from the $<D>^{exp}_{l=0}$, separately for nuclei of given even-odd character.

The results are summarized in Table 1. It can be noticed that the rms is smaller, compared to the global analysis, in three of the four sub-sets. This fact can allow a more accurate determination of the level density parameters for nuclei of unknown resonance spacings.

Table 1 Parametrization of the $a(*)$-systematics according to Eq. (24).

nuclei	α (MeV^{-1})	β	rms (MeV^{-1})	number of nuclei
all	0.058105	-5.8970	0.978	217
even-even	0.068072	-4.1136	0.567	51
even-odd	0.053127	-7.1799	1.090	112
odd-even	0.066794	-3.9051	0.767	8
odd-odd	0.065415	-4.4353	0.718	46

To have a better accuracy in the determination of the parameter a, a *local* systematics of $a(*)$ should be constructed. In fact, the small fluctuation of $a(*)$ in comparison with those of a allows for a much more reliable determination of this parameter and in turn for the level density at the neutron binding.

4.2 Calculation of the level density parameters for a given isotope

An example of calculation of level density parameters for a given isotope has been given in section 3.2. In that case, the level density parameter $a(*)$ for ^{153}Sm was evaluated from the systematics constructed as described in the previous example. If one wants to calculate the level density parameters that fit the known experimental level spacings $<D>^{exp}_{l=0} = 51.8 \pm 3.3$ eV, one should select the option 2 in the menu shown in section 3.2. In this case the program will evaluate the level density parameter $a(*)$ which is consistent with the measured level spacings and then it will calculate the other related parameters like the spin dispersion factor σ, the nuclear temperature T, and so forth. The results will appear as

```
Parameters actually available:
****  153Sm  ****
Atomic number Z= 62   Neutron number  N= 91
Target spin-parity       :            .0+
Neutron binding (Sn)     :      5.86737    MeV
En (above Sn)            :       .00000    MeV
delta (back-shift)       :       .97014    MeV
U (Sn+En-delta)          :      4.89722    MeV
Temperature              :       .51943    MeV
Shell correction (Esh)   :      3.67499    MeV
Deformation (Beta2)      :       .00000
Zcoll (J=¦It-1/2¦)       :      1.00000
Zcoll (J= It+1/2 )       :      1.00000
sigma2                   :     31.57597
gamma                    :       .07479    MeV**-1
a(*)                     :     18.92682    MeV**-1
a                        :     23.28252    MeV**-1

Experimental <D(l=0)>    :       .05180 +/-        .00330 KeV
Calculated   <D(l=0)>    :       .05180                   KeV
             <D(l=1)>    :       .01782                   KeV
```

As one can see, there are small differences in comparison with the parameters shown previously. These are due to the difference between the value derived *from the systematics* and the valued derived *from the experimental level spacings* $<D>^{exp}_{l=0}$.

5. CONCLUSIONS

We have described a well established technique to evaluate the FGM parametrization of nuclear level density at energies corresponding to the neutron binding energy. The model has been coded into a computer program, HERMES, which allows for the calculation of level density parameters. HERMES can be used as a stand-alone program as well as a part of a more general program for nuclear reaction calculations which uses the FGM prescriptions for the nuclear level density.

An example of application of HERMES has been given in which a parameter systematics for the nuclear level density has been constructed. Our parametrization can be easily incorporated into those computer codes that use the FGM prescriptions for the calculation of nuclear level densities. Our analysis included pairing correlations as well as shell inhomogeneities effects into the relations based on the FGM.

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APPENDIX A

Here follows printout of the file containing the level density parameter systematics calculated by HERMES as described in the text.

This file contains the level density parameter systematics as contructed by the HERMES code

Z	N	A	Spin	P	<D(l=0)> KeV	err<D(l=0)> KeV	a MeV**-1	-a MeV**-1	+a MeV**-1	a(*) MeV**-1	-a(*) MeV**-1	+a(*) MeV**-1	Esh MeV	Sn MeV	delta MeV	T MeV	sigma**2	Beta2
20	21	41	.0	1	45.00000	6.00000	6.2083	-.1104	.1276	6.2845	-.1117	.1291	-.14859	8.36337	1.87409	1.27309	8.62000	.00000
21	25	46	3.5	-1	1.30000	.10000	6.9583	-.0641	.0696	6.3039	-.0581	.0631	1.45773	8.76136	.00000	1.33599	10.95820	.00000
22	25	47	.0	1	10.00000	8.00000	7.4595	-.5420	1.6004	7.0655	-.5134	1.5159	.72780	8.87737	1.75038	1.17970	10.02941	.00000
22	26	48	2.5	-1	2.20000	.40000	6.9146	-.1449	.1763	6.5961	-.1382	.1682	.66504	11.62736	3.46410	1.30340	11.47679	.26900
22	27	49	.0	1	13.00000	3.00000	7.8437	-.2089	.2684	7.6955	-.2050	.2634	.24534	8.14237	1.71429	1.09869	10.01247	.00000
22	28	50	3.5	-1	5.00000	.50000	6.6417	-.0859	.0956	6.8764	-.0890	.0989	-.46062	10.93937	3.39411	1.29442	12.20017	.16600
22	29	51	.0	1	125.00000	70.00000	7.0890	-.4789	.9352	7.2812	-.4919	.9606	-.31188	6.37237	1.68034	1.03868	10.11826	.00000
23	28	51	6.0	1	2.70000	.70000	6.4900	-.1962	.2604	6.7864	-.2052	.2723	-.64335	11.05137	1.68034	1.43100	13.94003	.00000
24	27	51	.0	1	15.00000	2.00000	6.9648	-.1098	.1267	7.5715	-.1194	.1378	-1.08758	9.26236	1.68034	1.26013	12.27550	.00000
24	29	53	.0	1	42.00000	5.00000	6.9833	-.1074	.1221	7.6564	-.1177	.1339	-1.13272	7.93937	1.64833	1.16974	12.14947	.00000
24	30	54	1.5	-1	7.10000	1.20000	7.4310	-.1543	.1852	7.6097	-.1580	.1896	-.30627	9.71936	3.26599	1.13717	12.18488	.25000
24	31	55	.0	1	26.00000	7.00000	9.2518	-.3037	.4082	8.9343	-.2932	.3942	.42675	6.24538	1.61808	.87423	9.65835	.00000
25	31	56	2.5	-1	2.70000	.40000	7.6072	-.1327	.1556	7.9820	-.1392	.1633	-.64119	7.27037	.00000	1.17513	13.37846	.00000
26	29	55	.0	1	13.00000	2.00000	7.1928	-.1270	.1498	9.1602	-.1617	.1908	-2.97659	9.29837	1.61808	1.24225	13.72424	.00000
26	31	57	.0	1	17.00000	2.00000	8.2765	-.1187	.1348	9.2052	-.1321	.1499	-1.30802	7.64538	1.58944	1.03881	12.18059	.00000
26	32	58	.5	-1	6.00000	1.00000	7.9840	-.1523	.1822	8.3072	-.1585	.1896	-.52644	10.04536	3.15135	1.11752	13.48890	.25870
26	33	59	.0	1	35.00000	15.00000	8.6192	-.4192	.6814	8.4278	-.4098	.6663	.28292	6.58038	1.56227	.94208	11.69988	.00000
27	33	60	3.5	-1	1.10000	.10000	8.3994	-.0884	.0974	8.7783	-.0924	.1018	-.60446	7.49236	.00000	1.12112	14.31893	.00000
28	31	59	.0	1	13.70000	2.00000	7.4652	-.1252	.1465	9.5852	-.1608	.1880	-3.07872	8.99937	1.56227	1.19931	14.89447	.00000
28	33	61	.0	1	16.00000	2.50000	8.3086	-.1526	.1805	9.1695	-.1684	.1992	-1.25008	7.82037	1.53644	1.05158	13.80592	.00000
28	34	62	1.5	-1	1.80000	.30000	8.2193	-.1495	.1787	8.6896	-.1580	.1890	-.76557	10.59737	3.04800	1.13914	15.36641	.19780
28	35	63	.0	1	19.10000	3.60000	9.1820	-.2063	.2529	9.0701	-.2037	.2499	.15854	6.83837	1.51186	.92741	12.84830	.00000
28	37	65	.0	1	19.90000	3.60000	10.1697	-.2242	.2728	9.2604	-.2042	.2484	1.23043	6.09738	1.48842	.82358	12.01987	.00000
29	35	64	1.5	-1	.32000	.03000	9.7236	-.0933	.1031	9.8987	-.0950	.1049	-.25614	7.91636	.00000	1.05221	14.96497	.00000
29	37	66	1.5	-1	.51000	.06000	10.1324	-.1247	.1414	9.5106	-.1171	.1327	.91826	7.06537	.00000	.97980	14.66842	.00000
30	35	65	.0	1	3.44000	.23000	9.9689	-.0743	.0798	9.5875	-.0714	.0767	.54284	7.98037	1.48842	.95544	13.94435	.00000
30	37	67	.0	1	4.70000	.40000	10.7863	-.1047	.1147	9.4617	-.0919	.1006	1.84816	7.05236	1.46603	.85779	13.16780	.00000
30	38	68	2.5	-1	.51000	.02000	9.7021	-.0420	.0438	8.5335	-.0370	.0385	1.95529	10.19837	2.91043	1.01803	16.01836	.20500
30	39	69	.0	1	5.77000	.73000	11.4141	-.1649	.1888	9.4824	-.1370	.1569	2.64392	6.48236	1.44463	.79548	12.82480	.00000
30	41	71	.0	1	6.90000	1.00000	12.3558	-.2077	.2427	9.8249	-.1651	.1930	3.27477	5.83337	1.42414	.71917	12.15999	.00000
31	39	70	1.5	-1	.18100	.03500	10.8199	-.1975	.2426	9.3269	-.1702	.2091	2.33707	7.65436	.00000	.97501	16.10080	.00000
31	41	72	1.5	-1	.22500	.04800	12.0095	-.2460	.3091	9.6584	-.1978	.2486	3.40789	6.52137	.00000	.85810	14.85139	.00000
32	39	71	.0	1	.93000	.36000	12.5243	-.4377	.6707	10.1304	-.3541	.5425	3.22195	7.41537	1.42414	.80828	13.66680	.00000
32	41	73	.0	1	.96000	.40000	13.6080	-.5118	.8130	10.6181	-.3993	.6343	3.76393	6.78237	1.40449	.73622	13.03834	.00000
32	42	74	4.5	1	.08200	.02000	11.8233	-.2687	.3491	9.6912	-.2202	.2861	3.21956	10.20037	2.78994	.91370	16.55252	.28250

Z	N	A	Spin	P	<D(l=0)> KeV	err<D(l=0)> KeV	a MeV**-1	-a MeV**-1	+a MeV**-1	a(*) MeV**-1	-a(*) MeV**-1	+a(*) MeV**-1	Esh MeV	Sn MeV	delta MeV	T MeV	sigma**2	Beta2
32	43	75	.0	1	3.00000	1.50000	12.4968	-.5801	1.0268	9.9579	-.4623	.8182	3.39347	6.50537	1.38564	.75862	14.05393	.00000
32	45	77	.0	1	3.75000	2.00000	13.0259	-.6494	1.2032	10.8716	-.5420	1.0042	2.60792	6.07237	1.36753	.71519	13.84351	.00000
33	43	76	1.5	-1	.07500	.00500	12.4654	-.0796	.0854	9.9540	-.0635	.0682	3.70182	7.32637	.00000	.88201	16.70457	.00000
34	41	75	.0	1	.42000	.24000	12.7907	-.5814	1.1292	10.1425	-.4610	.8954	3.71024	8.02738	1.38564	.83366	15.44420	.00000
34	43	77	.0	1	.66700	.27000	13.1567	-.4647	.7268	10.3612	-.3660	.5724	3.76274	7.41838	1.36753	.78865	15.26549	.00000
34	44	78	.5	-1	.14600	.03000	11.9111	-.2169	.2698	9.8298	-.1790	.2226	3.18450	10.49836	2.71746	.92884	18.36989	.27120
34	45	79	.0	1	1.39000	.50000	12.9395	-.4312	.6398	10.4729	-.3490	.5178	3.24474	6.96237	1.35011	.77179	15.59142	.00000
34	47	81	.0	1	3.50000	1.50000	12.1320	-.4922	.7947	10.5890	-.4296	.6936	1.99944	6.70037	1.33333	.78704	16.57605	.00000
34	49	83	.0	1	6.70000	4.70000	12.8147	-.8131	1.9591	12.0876	-.7670	1.8479	.80056	5.81837	1.31717	.70943	15.56132	.00000
35	45	80	1.5	-1	.04700	.00500	12.4620	-.1202	.1344	10.1915	-.0983	.1099	3.38537	7.89237	.00000	.91058	18.78496	.00000
35	47	82	1.5	-1	.09400	.01500	12.0675	-.1759	.2082	10.5990	-.1545	.1829	2.09169	7.59337	.00000	.91239	19.61297	.00000
37	49	86	2.5	-1	.20000	.04500	9.9370	-.2050	.2608	9.9323	-.2049	.2607	.00750	8.65037	.00000	1.07841	25.09709	.00000
37	51	88	1.5	-1	2.64000	.88000	10.0951	-.3418	.4927	10.4060	-.3523	.5079	-.43130	6.07936	.00000	.92335	22.32781	.00000
38	47	85	.0	1	.38300	.13000	12.4947	-.3585	.5183	11.1140	-.3189	.4610	1.86351	8.53037	1.30158	.87582	19.98874	.00000
38	49	87	.0	1	.50000	.06600	12.3495	-.1527	.1755	12.3671	-.1529	.1757	-.02138	8.42837	1.28654	.87723	20.81216	.00000
38	50	88	4.5	1	.12100	.01300	10.3893	-.1084	.1214	11.4754	-.1197	.1341	-1.50869	11.11336	2.55841	1.04614	25.29695	.11740
38	51	89	.0	1	25.00000	5.00000	10.2035	-.2353	.2921	10.9551	-.2526	.3136	-.95371	6.36537	1.27200	.85473	21.06134	.00000
39	51	90	.5	-1	4.00000	.40000	9.5569	-.1042	.1159	10.4575	-.1140	.1268	-1.29012	6.85736	.00000	1.00175	25.14807	.00000
40	51	91	.0	1	6.40000	1.10000	10.8850	-.1982	.2383	11.8948	-.2166	.2604	-1.22872	7.19437	1.25794	.87448	22.36105	.00000
40	52	92	2.5	1	.57000	.10000	11.6997	-.2096	.2529	11.7016	-.2097	.2529	-.00238	8.63537	2.50217	.84936	22.11806	.10280
40	53	93	.0	1	2.60000	.70000	12.8276	-.3369	.4507	12.4107	-.3259	.4360	.48014	6.73436	1.24434	.76871	20.38164	.00000
40	55	95	.0	1	3.60000	.80000	12.8808	-.2908	.3693	11.6442	-.2629	.3339	1.51046	6.46337	1.23117	.75181	20.65328	.00000
40	57	97	.0	1	4.50000	1.00000	14.3841	-.3355	.4262	12.1794	-.2841	.3609	2.49894	5.57936	1.21842	.65380	18.59546	.00000
41	53	94	4.5	1	.04400	.00400	13.3071	-.1144	.1258	12.8203	-.1102	.1212	.58334	7.22937	.00000	.84472	22.80000	.00000
42	51	93	.0	1	2.10000	.30000	11.2038	-.1593	.1854	12.7641	-.1815	.2112	-1.84322	8.06737	1.24434	.91056	24.14279	.00000
42	53	95	.0	1	.97500	.26000	13.2105	-.3228	.4295	13.1254	-.3207	.4268	.09556	7.36737	1.23117	.79141	21.74124	.00000
42	54	96	2.5	1	.05500	.00800	14.0892	-.1867	.2178	13.1956	-.1748	.2040	1.02426	9.15437	2.44949	.79166	22.13085	.17200
42	55	97	.0	1	.85000	.04500	14.4119	-.0773	.0820	12.9023	-.0692	.0734	1.69830	6.82137	1.21842	.72426	20.59950	.00000
42	56	98	2.5	1	.03200	.00300	15.8147	-.1361	.1501	13.5815	-.1168	.1289	2.45217	8.64237	2.42437	.71748	20.75842	.16740
42	57	99	.0	1	.97000	.20000	16.2184	-.3230	.4027	13.0822	-.2605	.3248	3.37660	5.92537	1.20605	.62935	18.51935	.00000
42	59	101	.0	1	.40000	.08000	19.4903	-.3660	.4531	14.5799	-.2738	.3389	4.67159	5.39837	1.19404	.53886	16.39401	.00000
43	57	100	4.5	1	.01070	.00180	16.2372	-.2341	.2792	13.5587	-.1955	.2332	3.02511	6.76437	.00000	.73285	21.92924	.00000
44	56	100	2.5	1	.02500	.00200	14.3797	-.1030	.1121	13.2822	-.0951	.1035	1.29046	9.67238	2.40000	.81019	24.24338	.21720
44	60	104	.5	-1	.01600	.00100	17.8075	-.0947	.1011	14.4085	-.0766	.0818	3.61820	8.90936	2.35339	.68614	21.91831	.24430
47	61	108	.5	-1	.01600	.00300	16.5539	-.2454	.2990	14.2914	-.2118	.2582	2.51841	7.26937	.00000	.74789	25.44214	.00000
47	63	110	.5	-1	.01400	.00200	17.6982	-.2039	.2369	14.5646	-.1678	.1950	3.37874	6.80937	.00000	.69999	24.55184	.00000
48	59	107	.0	1	.13500	.03500	15.3288	-.3258	.4298	14.9976	-.3188	.4205	.34394	7.92936	1.16008	.75749	25.37198	.00000
48	61	109	.0	1	.12000	.03000	16.6558	-.3436	.4486	15.1066	-.3116	.4069	1.56982	7.34737	1.14939	.69560	24.02933	.00000
48	63	111	.0	1	.15500	.02000	17.1005	-.1954	.2239	14.7801	-.1689	.1935	2.38135	6.97537	1.13899	.66776	23.77744	.00000
48	64	112	.5	1	.02000	.00400	16.6119	-.2631	.3250	14.4316	-.2285	.2823	2.41201	9.39837	2.26779	.74018	26.75315	.18630

Z	N	A	Spin	P	<D(l=0)> KeV	err<D(l=0)> KeV	a MeV**-1	-a MeV**-1	+a MeV**-1	a(*) MeV**-1	-a(*) MeV**-1	+a(*) MeV**-1	Esh MeV	Sn MeV	delta MeV	T MeV	sigma**2	Beta2
48	65	113	.0	1	.19000	.02500	17.8437	-.2109	.2423	14.9240	-.1764	.2027	2.93325	6.54037	1.12887	.63096	23.14602	.00000
48	66	114	.5	1	.02100	.00400	17.2443	-.2625	.3210	14.7004	-.2238	.2737	2.74028	9.04238	2.24781	.70966	26.41794	.19120
48	67	115	.0	1	.23500	.03500	18.5785	-.2505	.2932	15.3576	-.2070	.2424	3.11254	6.14136	1.11901	.59722	22.55811	.00000
48	69	117	.0	1	.39000	.09000	18.7826	-.3894	.4983	15.6602	-.3247	.4155	2.93176	5.76737	1.10940	.57481	22.34454	.00000
49	67	116	4.5	1	.00940	.00020	16.7654	-.0321	.0328	14.4115	-.0276	.0282	2.59673	6.78437	.00000	.72059	27.61374	.00000
50	69	119	.0	1	.87000	.39000	15.6006	-.5850	.9646	14.2234	-.5333	.8794	1.47037	6.48537	1.10004	.68031	27.20376	.00000
50	71	121	.0	1	1.40000	.17000	15.5724	-.1871	.2128	14.6302	-.1757	.1999	.97115	6.17138	1.09091	.66458	27.32294	.00000
51	71	122	2.5	1	.01800	.00200	16.2572	-.1548	.1740	14.7213	-.1402	.1576	1.68107	6.80638	.00000	.73430	30.60667	.00000
51	73	124	3.5	1	.03800	.00400	15.5820	-.1482	.1655	14.8721	-.1414	.1580	.76274	6.46836	.00000	.73593	31.51694	.00000
52	71	123	.0	1	.13200	.01500	17.7423	-.1766	.1990	15.7303	-.1565	.1764	1.99371	6.93338	1.08200	.65459	27.65769	.00000
52	72	124	.5	1	.02500	.00400	16.3998	-.2109	.2496	15.1923	-.1953	.2312	1.30766	9.42537	2.15526	.75189	32.20045	.16950
52	73	125	.0	1	.13000	.01500	18.7084	-.1897	.2142	17.3122	-.1756	.1982	1.24601	6.57137	1.07331	.61832	26.83701	.00000
52	74	126	.5	1	.03800	.00300	16.3849	-.1102	.1197	16.0302	-.1078	.1171	.36161	9.11337	2.13809	.73886	32.49776	.15340
52	75	127	.0	1	.21000	.02000	18.6601	-.1617	.1787	18.5430	-.1606	.1776	.09700	6.29037	1.06483	.60588	27.00239	.00000
52	77	129	.0	1	.26000	.03000	18.8904	-.1987	.2245	20.8902	-.2198	.2482	-1.46596	6.08638	1.05654	.59191	27.07583	.00000
52	79	131	.0	1	.87000	.14000	17.2014	-.2615	.3103	22.1539	-.3368	.3996	-3.41882	5.92937	1.04844	.61683	28.94851	.00000
53	75	128	2.5	1	.00970	.00080	17.3075	-.1203	.1311	16.6564	-.1157	.1262	.63786	6.82537	.00000	.70959	32.04037	.00000
55	79	134	3.5	1	.02065	.00230	15.9295	-.1532	.1723	16.8634	-.1622	.1824	-.91642	6.89137	.00000	.74684	36.39777	.00000
56	80	136	1.5	1	.04000	.00700	15.5149	-.2260	.2719	16.9599	-.2471	.2972	-1.42299	9.10736	2.05798	.76557	38.24337	.12420
56	81	137	.0	1	.43000	.03500	16.2275	-.1222	.1332	18.8855	-.1422	.1550	-2.25843	6.89837	1.02523	.68994	34.88893	.00000
56	82	138	1.5	1	.29000	.04000	13.6151	-.1746	.2021	16.8316	-.2159	.2499	-3.14940	8.61137	2.04302	.80037	40.96641	.09250
56	83	139	.0	1	6.30000	1.70000	17.2238	-.4737	.6346	20.2783	-.5577	.7472	-2.24300	4.72337	1.01783	.54987	28.48547	.00000
57	83	140	3.5	1	.20800	.01000	16.0715	-.0786	.0827	17.6697	-.0864	.0909	-1.42295	5.16137	.00000	.65685	34.43664	.00000
58	83	141	.0	1	3.20000	.20000	16.4449	-.1088	.1162	17.6939	-.1170	.1251	-1.08323	5.42837	1.01058	.60738	32.22312	.00000
59	83	142	2.5	1	.08800	.00900	16.2927	-.1537	.1712	16.7524	-.1581	.1761	-.44399	5.84337	.00000	.68687	36.87180	.00000
60	83	143	.0	1	.44000	.05200	18.1517	-.1973	.2235	18.6503	-.2027	.2297	-.42246	6.12437	1.00349	.61027	33.14529	.00000
60	84	144	3.5	-1	.04500	.00400	17.1722	-.1393	.1530	16.8217	-.1365	.1499	.33809	7.81637	2.00000	.66519	36.55001	.13090
60	85	145	.0	1	.43000	.06500	19.2953	-.2658	.3116	18.0220	-.2483	.2910	1.10619	5.75537	.99655	.57112	31.74548	.00000
60	86	146	3.5	-1	.02200	.00200	19.0325	-.1533	.1688	17.2438	-.1389	.1529	1.67526	7.56536	1.98625	.61616	34.64382	.15240
60	87	147	.0	1	.23500	.02900	22.1609	-.2480	.2825	19.0930	-.2136	.2434	2.48450	5.29237	.98974	.50532	28.73639	.00000
60	89	149	.0	1	.14000	.01500	24.4388	-.2351	.2632	19.8928	-.1914	.2142	3.51575	5.03837	.98308	.46585	27.09527	.00000
60	91	151	.0	1	.17400	.02000	22.7305	-.2337	.2638	18.6644	-.1919	.2166	3.40074	5.33437	.97655	.50075	29.77969	.00000
61	87	148	3.5	1	.00360	.00050	21.4578	-.2377	.2752	18.2693	-.2024	.2343	2.86022	5.89337	.00000	.58961	33.91106	.00000
62	86	148	3.5	-1	.00570	.00050	19.8820	-.1446	.1585	17.7093	-.1288	.1412	2.03008	8.14137	1.97279	.62788	36.11218	.14230
62	88	150	3.5	-1	.00220	.00020	22.0234	-.1600	.1753	18.4109	-.1338	.1466	3.24210	7.98536	1.95959	.58674	34.50960	.19310
62	89	151	.0	1	.05500	.00900	24.1590	-.3269	.3885	19.2982	-.2611	.3103	3.96866	5.59737	.97655	.49602	29.49888	.00000
62	90	152	2.5	-1	.00120	.00020	22.6913	-.2794	.3327	18.6578	-.2298	.2736	3.62001	8.25737	1.94666	.58888	35.40820	.30550
62	91	153	.0	1	.05180	.00330	23.2825	-.1274	.1361	18.9268	-.1036	.1107	3.67499	5.86737	.97014	.51943	31.57597	.00000
62	93	155	.0	1	.11500	.01200	21.9158	-.1990	.2222	18.5165	-.1682	.1877	2.93664	5.80737	.96386	.53502	33.23531	.00000
63	89	152	2.5	1	.00073	.00007	23.6207	-.1698	.1878	18.8727	-.1356	.1500	4.21192	6.30537	.00000	.57562	34.61134	.00000

Z	N	A	Spin	P	<D(l=0)> KeV	err<D(l=0)> KeV	a MeV**-1	-a MeV**-1	+a MeV**-1	a(*) MeV**-1	-a(*) MeV**-1	+a(*) MeV**-1	Esh MeV	Sn MeV	delta MeV	T MeV	sigma**2	Beta2
63	90	153	3.0	-1	.00025	.00004	21.8828	-.2421	.2863	17.9193	-.1983	.2344	3.87494	8.55336	.97014	.65194	39.63069	.00000
63	91	154	2.5	1	.00130	.00020	22.2281	-.2541	.2989	18.2606	-.2087	.2455	3.66708	6.44137	.00000	.60111	36.94004	.00000
63	92	155	3.0	-1	.00092	.00017	20.7379	-.2757	.3348	17.4045	-.2314	.2810	3.32135	8.15137	.96386	.65587	40.74218	.00000
64	89	153	.0	1	.01500	.00200	24.4301	-.2553	.2937	19.6135	-.2050	.2358	3.97410	6.24736	.97014	.52227	31.74828	.00000
64	91	155	.0	1	.01450	.00150	23.8717	-.1952	.2174	19.4669	-.1592	.1773	3.69958	6.43537	.96386	.53755	33.39206	.00000
64	92	156	1.5	-1	.00180	.00020	21.8335	-.1826	.2050	18.3216	-.1532	.1721	3.26535	8.53637	1.92154	.61432	38.57247	.33780
64	93	157	.0	1	.03780	.00550	22.2923	-.2610	.3042	18.7934	-.2201	.2565	3.04726	6.35937	.95770	.55553	35.25464	.00000
64	94	158	1.5	-1	.00490	.00040	21.7308	-.1417	.1544	18.6095	-.1213	.1322	2.80996	7.93837	1.90934	.59130	37.92377	.34840
64	95	159	.0	1	.08500	.00300	22.1373	-.0691	.0717	19.0483	-.0594	.0617	2.62575	5.94236	.95166	.53890	34.92804	.00000
64	97	161	.0	1	.20200	.02000	21.5093	-.1904	.2112	18.8799	-.1671	.1854	2.23938	5.63536	.94573	.53331	35.29369	.00000
65	95	160	1.5	1	.00390	.00040	21.2322	-.1696	.1889	18.4352	-.1473	.1641	2.58048	6.37537	.00000	.61393	40.20915	.00000
66	91	157	.0	1	.00270	.00040	25.3988	-.2705	.3159	20.9003	-.2226	.2599	3.59764	6.96936	.95770	.54126	34.34906	.00000
66	95	161	.0	1	.02700	.00170	22.7177	-.1176	.1256	19.4643	-.1008	.1077	2.76452	6.45337	.94573	.55433	36.68444	.00000
66	96	162	2.5	1	.00267	.00013	21.5195	-.0839	.0883	18.8021	-.0733	.0771	2.46070	8.19637	1.88562	.60660	40.56027	.34070
66	97	163	.0	1	.06460	.00190	21.6676	-.0553	.0571	19.1557	-.0489	.0505	2.16294	6.27137	.93991	.56132	37.91985	.00000
66	98	164	2.5	-1	.00685	.00054	21.3683	-.1389	.1509	19.0783	-.1240	.1348	2.01404	7.65837	1.87409	.58619	40.00555	.34810
66	99	165	.0	1	.14700	.00900	21.9491	-.1201	.1281	19.6450	-.1075	.1146	1.90496	5.71637	.93420	.53164	36.65175	.00000
67	99	166	3.5	-1	.00460	.00050	20.4827	-.1786	.2003	18.6157	-.1623	.1820	1.71473	6.24437	.00000	.62075	43.22879	.00000
68	95	163	.0	1	.00690	.00120	23.9280	-.3053	.3664	20.2716	-.2586	.3105	3.03986	6.90137	.93991	.55749	37.66066	.00000
68	97	165	.0	1	.02000	.00300	22.7407	-.2642	.3095	19.7208	-.2291	.2684	2.56773	6.65036	.93420	.56310	38.82072	.00000
68	99	167	.0	1	.03800	.00300	22.2391	-.1447	.1572	19.9506	-.1298	.1410	1.91604	6.43537	.92859	.56098	39.45893	.00000
68	100	168	3.5	1	.00400	.00020	21.6841	-.0895	.0942	19.5588	-.0807	.0850	1.84350	7.77137	1.85164	.58729	41.72279	.33810
68	101	169	.0	1	.09400	.01000	21.9335	-.1984	.2218	19.9312	-.1803	.2016	1.65936	6.00337	.92308	.54592	39.16921	.00000
68	103	171	.0	1	.12500	.02500	22.5272	-.3732	.4613	20.6156	-.3415	.4221	1.52016	5.68137	.91766	.52296	38.26479	.00000
69	101	170	.5	1	.00730	.00050	20.9737	-.1124	.1208	19.2903	-.1034	.1111	1.51905	6.59337	.00000	.62737	45.45807	.00000
70	100	170	3.5	1	.00220	.00050	20.8445	-.3472	.4414	18.5889	-.3096	.3936	2.11461	8.46937	1.84072	.63102	45.72297	.32350
70	101	171	.0	1	.03700	.00600	21.8123	-.2783	.3302	19.6279	-.2504	.2971	1.88290	6.61437	.91766	.57559	42.11621	.00000
70	102	172	.5	-1	.00580	.00050	22.5247	-.1501	.1642	20.4536	-.1363	.1491	1.74443	8.02037	1.82998	.58630	43.31886	.33020
70	103	173	.0	1	.07000	.00300	21.4102	-.0787	.0824	19.7651	-.0727	.0761	1.40119	6.36737	.91234	.57078	42.58162	.00000
70	104	174	2.5	-1	.00780	.00090	21.7995	-.2042	.2305	20.0767	-.1881	.2123	1.45611	7.46437	1.81944	.57349	43.19661	.32500
70	105	175	.0	1	.16200	.01800	21.5866	-.2082	.2340	20.0058	-.1930	.2168	1.31049	5.82237	.90711	.54308	41.29871	.00000
70	107	177	.0	1	.18000	.02000	22.3164	-.2171	.2440	20.5909	-.2003	.2252	1.38255	5.56637	.90198	.52101	40.37785	.00000
71	105	176	3.5	1	.00345	.00015	21.0812	-.0746	.0781	19.5337	-.0691	.0723	1.37778	6.29237	.00000	.61285	47.04881	.00000
71	106	177	7.0	-1	.00174	.00017	22.3331	-.1734	.1920	20.2949	-.1575	.1745	1.74214	7.07237	.90198	.58827	45.59059	.00000
72	103	175	.0	1	.02100	.00500	22.6589	-.3997	.5143	20.2551	-.3573	.4597	2.02746	6.70837	.90711	.56791	43.18646	.00000
72	105	177	.0	1	.03200	.00700	22.9305	-.3827	.4824	20.7750	-.3467	.4370	1.75913	6.38337	.90198	.55027	42.64572	.00000
72	106	178	3.5	-1	.00240	.00030	23.1654	-.2248	.2563	20.9304	-.2031	.2316	1.83417	7.62537	1.79888	.56198	43.96376	.28030
72	107	179	.0	1	.06200	.01100	22.6200	-.3217	.3879	20.6447	-.2936	.3540	1.61228	6.10037	.89692	.54208	42.80475	.00000
72	108	180	3.5	1	.00440	.00020	22.7858	-.0859	.0900	20.8613	-.0786	.0824	1.57742	7.38737	1.78885	.55737	44.42265	.27330
72	109	181	.0	1	.09400	.01100	23.2583	-.2299	.2600	21.4265	-.2118	.2395	1.42599	5.69636	.89195	.51545	41.46264	.00000

Z	N	A	Spin	P	<D(l=0)> KeV	err<D(l=0)> KeV	a MeV**-1	-a MeV**-1	+a MeV**-1	a(*) MeV**-1	-a(*) MeV**-1	+a(*) MeV**-1	Esh MeV	Sn MeV	delta MeV	T MeV	sigma**2	Beta2
73	108	181	8.0	1	.00110	.00010	21.8017	-.1545	.1699	20.1817	-.1430	.1573	1.42443	7.57637	.89195	.61767	49.68560	.00000
73	109	182	3.5	1	.00417	.00004	21.5118	-.0172	.0174	20.1543	-.0161	.0163	1.17304	6.06337	.00000	.59616	48.39714	.00000
73	110	183	3.0	-1	.00470	.00120	21.5385	-.4084	.5357	19.8158	-.3758	.4928	1.51540	6.93337	.88707	.59500	48.74683	.00000
74	107	181	.0	1	.02250	.00650	22.7204	-.4756	.6472	20.9953	-.4395	.5981	1.41604	6.68237	.89195	.56658	45.57546	.00000
74	109	183	.0	1	.06600	.00400	22.2680	-.1142	.1217	20.9016	-.1072	.1142	1.11207	6.19137	.88707	.55149	45.18179	.00000
74	110	184	.5	-1	.01200	.00100	23.1630	-.1540	.1681	21.6167	-.1438	.1568	1.23226	7.41137	1.76930	.55413	45.81229	.23470
74	111	185	.0	1	.08100	.00500	23.4268	-.1242	.1326	21.8408	-.1158	.1236	1.22139	5.75437	.88226	.51647	43.08603	.00000
74	113	187	.0	1	.08700	.00700	24.4471	-.1688	.1837	22.8354	-.1577	.1716	1.17960	5.46637	.87753	.49122	41.72094	.00000
75	111	186	2.5	1	.00310	.00020	22.1996	-.1132	.1211	21.0853	-.1075	.1150	.92919	6.17837	.00000	.59059	49.71398	.00000
75	113	188	2.5	1	.00410	.00030	22.6438	-.1323	.1428	21.6163	-.1263	.1363	.82991	5.87237	.00000	.57116	48.94390	.00000
76	111	187	.0	1	.02600	.00200	23.8374	-.1476	.1600	22.5499	-.1396	.1513	.98054	6.29137	.87753	.53549	45.48061	.00000
76	112	188	.5	-1	.00440	.00020	23.2898	-.0819	.0858	22.4066	-.0788	.0826	.69636	7.98937	1.75038	.57746	49.48312	.18590
76	113	189	.0	1	.04000	.00200	24.3409	-.1016	.1071	23.3647	-.0976	.1028	.71107	5.92137	.87287	.51330	44.37608	.00000
76	114	190	1.5	-1	.00330	.00020	23.2082	-.1099	.1170	22.8299	-.1081	.1151	.29182	7.79337	1.74114	.57088	49.78958	.17560
76	115	191	.0	1	.07000	.00500	23.8326	-.1442	.1554	23.6204	-.1429	.1541	.15259	5.75737	.86829	.51224	45.06856	.00000
76	117	193	.0	1	.11500	.01000	23.4896	-.1756	.1924	24.3995	-.1824	.1999	-.63160	5.58437	.86378	.50867	45.53824	.00000
77	115	192	1.5	1	.00180	.00014	23.8956	-.1402	.1521	23.9696	-.1407	.1525	-.05482	6.21237	.00000	.56817	50.42627	.00000
77	116	193	4.0	-1	.00060	.00010	22.7405	-.2689	.3200	23.3983	-.2767	.3293	-.51078	7.75737	.86378	.61165	54.75670	.00000
77	117	194	1.5	1	.00554	.00053	22.3014	-.1666	.1843	23.6586	-.1767	.1955	-1.01632	6.06637	.00000	.58435	52.76565	.00000
78	117	195	.0	1	.24000	.06500	20.2967	-.4429	.5917	22.1988	-.4845	.6472	-1.48046	6.10537	.85934	.57847	52.68424	.00000
78	118	196	.5	-1	.01800	.00300	21.0337	-.2688	.3207	23.9527	-.3062	.3652	-2.17478	7.92137	1.71429	.60996	56.02773	.13080
79	119	198	1.5	1	.01650	.00090	19.3252	-.0869	.0920	23.8798	-.1074	.1137	-3.44637	6.51237	.00000	.65330	61.03268	.00000
80	119	199	.0	1	.10500	.03300	20.2713	-.4808	.6739	26.4107	-.6264	.8780	-4.11321	6.66337	.85066	.60517	57.01337	.00000
80	120	200	.5	-1	.10000	.03000	17.9440	-.4156	.5737	24.3621	-.5643	.7789	-4.74577	8.02937	1.69706	.67296	63.93164	.09820
81	123	204	1.5	1	.36000	.05000	14.4820	-.1803	.2089	24.3639	-.3033	.3514	-7.42043	6.65637	.00000	.77687	76.27883	.00000
81	125	206	.5	1	5.50000	1.10000	12.0139	-.2304	.2854	23.9653	-.4595	.5692	-9.10346	6.50337	.00000	.85693	85.51941	.00000
82	123	205	.0	1	1.52000	.13000	15.7819	-.1261	.1380	27.4051	-.2189	.2396	-7.58479	6.73137	.83812	.70208	69.49967	.00000
82	125	207	.0	1	37.10000	5.50000	11.2894	-.1766	.2070	24.2243	-.3790	.4441	-9.57758	6.73837	.83406	.85392	85.91004	.00000
82	126	208	.5	-1	35.70000	6.50000	10.7460	-.2112	.2567	24.3933	-.4795	.5828	-9.98462	7.36737	1.66410	.86694	87.92264	.05440
83	127	210	4.5	-1	4.50000	.60000	13.4993	-.1998	.2305	24.1804	-.3580	.4129	-7.63330	4.60437	.00000	.69407	71.52212	.00000
88	139	227	.0	1	.03030	.00540	32.6456	-.4567	.5513	26.7281	-.3740	.4514	3.81028	4.56137	.79647	.38275	44.90583	.00000
90	140	230	2.5	1	.00053	.00015	30.4655	-.5747	.7768	25.8407	-.4875	.6589	3.23411	6.79336	1.58251	.45912	55.05708	.24410
90	141	231	.0	1	.00960	.00130	32.2759	-.3296	.3798	27.1630	-.2774	.3196	3.31385	5.11737	.78954	.40949	49.46187	.00000
90	143	233	.0	1	.01680	.00100	32.8841	-.1575	.1676	27.3301	-.1309	.1393	3.55027	4.78637	.78615	.39144	47.96588	.00000
91	141	232	1.5	-1	.00045	.00005	30.0566	-.2341	.2628	25.8825	-.2016	.2263	2.95360	5.57037	.00000	.47653	57.97602	.00000
91	143	234	1.5	-1	.00059	.00009	31.1109	-.3313	.3884	26.5638	-.2829	.3316	3.10898	5.21938	.00000	.45414	56.04786	.00000
92	141	233	.0	1	.00460	.00070	30.7251	-.3358	.3938	27.0254	-.2954	.3464	2.46349	5.74337	.78615	.44694	54.76681	.00000
92	142	234	2.5	1	.00055	.00005	30.1738	-.1994	.2191	26.4603	-.1749	.1921	2.55322	6.84337	1.56893	.46408	57.27390	.27190
92	143	235	.0	1	.01060	.00050	31.0576	-.1151	.1209	27.0704	-.1003	.1054	2.62104	5.29836	.78279	.42630	52.98729	.00000
92	144	236	3.5	-1	.00044	.00006	31.6506	-.3090	.3564	27.4713	-.2682	.3093	2.74974	6.54537	1.56227	.44065	55.15926	.28210

Z	N	A	Spin	P	<D(l=0)> KeV	err<D(l=0)> KeV	a MeV**-1	-a MeV**-1	+a MeV**-1	a(*) MeV**-1	-a(*) MeV**-1	+a(*) MeV**-1	Esh MeV	Sn MeV	delta MeV	T MeV	sigma**2	Beta2
92	145	237	.0	1	.01470	.00080	31.2367	-.1351	.1430	27.0580	-.1170	.1239	2.74058	5.12537	.77948	.41782	52.67223	.00000
92	146	238	.5	1	.00350	.00080	31.7446	-.5140	.6543	27.1771	-.4401	.5602	3.00915	6.15237	1.55569	.42445	53.88429	.28630
92	147	239	.0	1	.02090	.00110	32.2650	-.1378	.1456	27.4719	-.1174	.1240	3.07377	4.80736	.77622	.39698	50.75001	.00000
93	145	238	2.5	1	.00052	.00004	29.4234	-.1643	.1782	26.1932	-.1463	.1586	2.26892	5.48837	.00000	.47901	60.81074	.00000
94	145	239	.0	1	.00900	.00070	29.7123	-.1761	.1911	26.9615	-.1598	.1734	1.84442	5.64737	.77622	.45185	57.76473	.00000
94	146	240	.5	1	.00230	.00010	30.7809	-.1010	.1056	27.5376	-.0903	.0945	2.13900	6.53337	1.54919	.44757	57.61693	.28910
94	147	241	.0	1	.01360	.00070	30.8508	-.1255	.1324	27.5006	-.1119	.1180	2.18050	5.24137	.77299	.42592	55.21182	.00000
94	148	242	2.5	1	.00090	.00010	31.7352	-.2599	.2918	27.9534	-.2289	.2571	2.44659	6.31036	1.54278	.43144	56.31438	.29170
94	149	243	.0	1	.01550	.00170	31.7398	-.2697	.3025	27.9008	-.2371	.2659	2.45327	5.03338	.76980	.41063	53.96828	.00000
95	147	242	2.5	-1	.00055	.00005	29.1655	-.1912	.2102	26.7419	-.1753	.1927	1.67778	5.53937	.00000	.48334	63.08901	.00000
95	148	243	5.0	-1	.00040	.00008	28.6871	-.3969	.4903	25.7800	-.3567	.4406	2.09339	6.36337	.76980	.48992	64.38816	.00000
95	149	244	2.5	-1	.00060	.00006	29.7786	-.2149	.2385	26.9050	-.1942	.2155	1.97151	5.36637	.00000	.47109	62.33951	.00000
96	147	243	.0	1	.02500	.00800	27.2139	-.6172	.8696	25.3325	-.5745	.8094	1.35111	5.69437	.76980	.47688	62.67541	.00000
96	148	244	2.5	1	.00110	.00020	28.8785	-.3737	.4521	26.6616	-.3450	.4174	1.53006	6.79937	1.53644	.47507	62.86567	.29720
96	149	245	.0	1	.01200	.00100	29.7482	-.1905	.2078	27.5416	-.1764	.1924	1.45342	5.52237	.76665	.44679	59.52743	.00000
96	150	246	3.5	1	.00140	.00010	29.4018	-.1614	.1739	26.8629	-.1475	.1589	1.72552	6.45637	1.53018	.45677	61.27177	.29830
96	151	247	.0	1	.03400	.00700	29.1401	-.4563	.5673	26.5245	-.4153	.5164	1.77351	5.15637	.76354	.43649	58.94869	.00000
96	152	248	4.5	-1	.00140	.00030	30.2940	-.4729	.5929	27.2273	-.4250	.5329	2.04622	6.21137	1.52400	.43945	59.75031	.29720
96	153	249	.0	1	.03300	.00500	31.8061	-.3790	.4444	28.1627	-.3356	.3935	2.30116	4.71337	.76047	.39677	54.30937	.00000
97	153	250	3.5	1	.00100	.00010	30.0835	-.2247	.2494	27.3719	-.2044	.2269	1.81910	4.96637	.00000	.45259	62.36595	.00000
98	152	250	4.5	-1	.00070	.00010	29.8967	-.3104	.3605	28.3352	-.2942	.3416	1.01604	6.62138	1.51789	.45968	63.34292	.29900
98	155	253	.0	1	.02700	.00300	31.8343	-.2801	.3147	28.5520	-.2513	.2823	2.06046	4.80537	.75443	.40084	56.34443	.00000

APPENDIX B (request-form)

To obtain HERMES, please fill in and send the following form:

Name :_____

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I would like to receive a copy of the package HERMES through:

☐ diskette (5.25") ☐ diskette (3.5") ☐ e-mail
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Date_____

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